

## **SECTION 03371**

### **SHOTCRETE**

#### **PART 1 - GENERAL**

##### **0.1 DESCRIPTION OF WORK**

- A.** Work Included: This Section specifies shotcrete applied by dry-mix or wet-mix process.
- B.** Related Work: The following items are not included in this Section and will be performed under the designated Sections:
  - 1. Section 03300 - CAST-IN-PLACE CONCRETE.

##### **0.2 DEFINITIONS**

- A.** Shotcrete: A prepackaged single component shrinkage compensated, microsilica enhanced, cement concrete with fibers, applied by the wet or dry process, from a spray nozzle by means of compressed air.
- B.** Dry-Mix Process: Shotcrete which is applied by the addition of water at the spray nozzle located on the end of the delivery hose.
- C.** Wet-Mix Shotcrete: Shotcrete which is applied with its ingredients mixed prior to introduction into delivery hose.
- D.** Rebound: Dry shotcrete that is rebounded from the wall, cured, and treated as waste.
- E.** Waste: Shotcrete that is used for charging the hoses, is mixed or sprayed, and is not applied to the walls as part of the work.

##### **0.3 SUBMITTALS**

- A.** Product Data: For manufactured materials and products including reinforcement and forming accessories, shotcrete materials, admixtures, and curing compounds.
- B.** Shop Drawings: For details of fabricating, bending, and placing reinforcement. Include support and anchor details, number and location of splices, and special reinforcement required for openings through shotcrete structures.

- C. Samples: Approximately 24 by 24 by 2 inches, to illustrate quality of finishes, colors, and textures of exposed surfaces of shotcrete.
- D. Design Mixes: For each shotcrete mix.
- E. Qualification Data: For Installer and testing agency.
- F. Material Test Reports: For shotcrete materials.
- G. Field quality-control test reports.

#### **0.4 QUALITY ASSURANCE**

- A. Manufacturer's Technical Representative: Furnish and pay for the services of a technical field representative, during project startup, to insure the proper application of the shotcrete system.
- B. Installer Qualifications:
  - 1. The Installer shall have a minimum of four years in the application of wet process shotcrete for concrete restoration. The contractor must have a minimum of 5 years of tunnel rehabilitation work and be experienced in similar type of work for rail and highway tunnels. The contractor must present a minimum of five concrete restoration projects for verification of tunnel work experience.
  - 2. Nozzlemen before employment on the work shall be a qualified Nozzleman as specified in ACI 5.6.2. In addition the Foremen, Nozzlemen, and Crewmen shall satisfy the Authority that each has done satisfactory work in similar capacities elsewhere for a sufficient period of time to be fully qualified to properly perform the work in accordance with the requirements indicated. Foremen shall have had at least three years experience as nozzlemen, and at least two years experience on similar work. Nozzlemen shall be qualified workmen, having had at least three years experience in similar work.
  - 3. Hold Point - Each shotcreting crew will be required to fabricate one acceptable test panel for each shooting position which the crew will encounter in the work, prior to application of shotcrete in the work, using the exact type of equipment intended to be used by the crew as identified by this specification.
  - 4. Should the results of control testing indicate that deficient shotcrete application is being produced by a crew, the crew may be required to be requalified for the shooting position in question.
- C. Testing Agency Qualifications: An independent agency qualified according to ASTM C 1077 and ASTM E 329 for testing indicated, and acceptable to authorities having jurisdiction.
- D. Comply with provisions of the following, unless more stringent requirements are indicated:

1. ACI 301, "Specifications for Structural Concrete".
2. ACI 506.2, "Specification for Shotcrete".

**E. Preconstruction Testing Service:** Contractor shall engage a qualified independent testing agency to perform preconstruction testing and inspections indicated below:

1. Produce test panels before shotcrete placement according to requirements in ACI 506.2 and ASTM C 1140 for each design mix, shooting orientation, and nozzle operator. Produce test panels with dimensions of 24 by 24 inches minimum and of average thickness of shotcrete, but not less than 3-1/2 inches. From each test panel, testing agency will obtain six test specimens: one set of three specimens unreinforced and one set of three specimens reinforced. Agency will perform the following:
  - a. Test each set of unreinforced specimens for compressive strength according to ASTM C 42.
  - b. Visually inspect each set of reinforced shotcrete cores taken from test panels and determine mean core grades according to ACI 506.2.

**F. Sample Area:** Apply a prepackaged single component, microsilica enhanced, cement shotcrete on a sample area not less than ten square feet in size. When approved, the sample area shall serve as a standard of acceptance for all subsequent application of products specified hereinafter.

**G. Determination of Shotcrete Proportions and Placement Procedures:**

1. Notification Point - Not less than 30 days in advance of the shotcrete placement, notify the Authority in writing as to the intended sources of shotcrete materials. Appropriate samples of shotcrete materials will be obtained by the contractor. Forward such samples to the Authority for testing and acceptance.
2. At a time and place mutually agreeable to the Contractor and Authority, provide the following for use in determination of shotcrete proportions and placement procedures, in sufficient quantities to perform the testing herein specified:
  - a. Shotcrete materials as accepted
  - b. Plywood back forms, each two feet square
  - c. Reinforcement of the types, sizes, and configurations to be used in the shotcrete, sufficient to place in one half of each test panel
  - d. Equipment of the exact type proposed for use in applying shotcrete
  - e. Personnel for operation of the shotcreting equipment
3. For the prepackaged shotcrete mix, fabricate test panels for each shooting position (i.e. slab, vertical, overhead) to be encountered in the work. Use trial mixes as designated by the Engineer, and modify as directed by the Engineer to produce satisfactory test panels. Test

panels shall have reinforcement installed over one half of the panel in the sizes and configurations to be installed in the work.

4. Satisfactory test panels shall consist of a minimum five inch thickness of dense, uniform shotcrete without rebound inclusions, segregation, voids, or weakness of bond between layers. For each satisfactory test panel produced, record the water content and details of the placement procedure such as nozzle distance, rate and angle of application, thickness of layers, time lapse between layers, time lapse between mixing and application, and the like. Cure satisfactory test panels in accordance with ASTM C31.
5. Satisfactory test panels will be tested by the Authority to determine conformance of the shotcrete to the specified requirements. Where the results of tests are unacceptable, fabricate additional satisfactory test panels using materials, mixing and application equipment, or application procedures, until acceptable test panels are achieved.
6. Hold Point - Do not apply any shotcrete in the work until the prepackaged mix and placement equipment and procedures have been accepted as specified herein. Approved mockups may become part of the completed Work if undamaged at time of Substantial Completion.

## **0.5 DELIVERY, STORAGE AND HANDLING**

- A. Deliver materials to the site in original packages or containers bearing the manufacturer's labels and identification.
- B. Store and handle materials to prevent inclusion of foreign matter and water and store at manufacturer's recommended temperatures and humidity. The storage temperature for the material shall be between 50 and 90 degrees F, unless indicated otherwise.
- C. Protection:
  1. Protect the railroad tracks, platforms, catenary system and ancillary systems from overspray and buildup of shotcrete, using plywood shields or other methods approved by the Authority.
  2. Protect electrical equipment, tunnel and railroad systems, including but not limited to CCTV, signal, telephone, track, and electrical cables, from overspray.

## **0.6 PROJECT CONDITIONS**

- A. Cold-Weather Shotcreting: Protect shotcrete work from physical damage or reduced strength caused by frost, freezing, or low temperatures according to ACI 306.1 and as follows:
  1. Discontinue shotcreting when ambient temperature is 40 deg F and falling. Uniformly heat water and aggregates before mixing to obtain

- a shotcrete shooting temperature of not less than 50 deg F and not more than 90 deg F.
2. Do not use frozen materials or materials containing ice or snow.
  3. Do not place shotcrete on frozen surfaces or surfaces containing frozen materials.
  4. Do not use calcium chloride, salt, or other materials containing antifreeze agents.
- B.** Hot-Weather Shotcreting: Mix, place, and protect shotcrete according to ACI 305R when hot-weather conditions and high temperatures would seriously impair quality and strength of shotcrete, and as follows:
1. Cool ingredients before mixing to maintain shotcrete temperature at time of placement below 100 deg F for dry mix or 90 deg F for wet mix.
  2. Reduce temperature of reinforcing steel and receiving surfaces below 100 deg F before shotcreting.

## **PART 2 - PRODUCTS**

### **0.1 FORM MATERIALS**

- A.** Forms: Form-facing panels that will provide continuous, straight, smooth, concrete surfaces. Furnish panels in largest practicable sizes to minimize number of joints.

### **0.2 REINFORCING MATERIALS**

- A.** Reinforcing Bars: ASTM A 615/A 615M, Grade 60, deformed.
- B.** Low-Alloy-Steel Reinforcing Bars: ASTM A 706/A 706M, deformed.
- C.** Galvanized Reinforcing Bars: ASTM A 767/A 767M, Class II, zinc coated, hot-dip galvanized after fabrication and bending, as follows:
1. Steel Reinforcement: ASTM A 615/A 615M, Grade 60, deformed.
- D.** Plain-Steel Wire: ASTM A 82, galvanized after fabrication.
- E.** Plain-Steel-Welded Wire Fabric: ASTM A 185, fabricated from galvanized steel wire into flat sheets.
- F.** Deformed-Steel-Welded Wire Fabric: ASTM A 497, flat sheet.
- G.** Supports: Bolsters, chairs, spacers, ties, and other devices for spacing, supporting, and fastening reinforcing steel in place according to CRSI's "Manual of Standard Practice" and as follows:

1. For uncoated reinforcement, use CRSI Class 1, plastic-protected bar supports.
  2. For zinc-coated reinforcement, use galvanized wire or dielectric-polymer-coated wirebar supports.
- H.** Reinforcing Anchors: ASTM A 36/A 36M, unheaded rods or ASTM A 307, Grade A, hex-head bolts; carbon steel; and carbon-steel nuts.
1. Finish: Hot-dip zinc coating, ASTM A 153/A 153M, Class C.

### **0.3 SHOTCRETE MATERIALS**

- A.** Portland Cement: ASTM C 150, Type I or III. Use only one brand and type of cement for Project.
1. Fly Ash: ASTM C 618, Class C or F.
  2. Ground Granulated Blast-Furnace Slag: ASTM C 989, Grade 100 or 120.
- B.** Silica Fume: ASTM C 1240, amorphous silica.
- C.** Normal-Weight Aggregates: ASTM C 33, from a single source, and as follows:
1. Aggregate Gradation: ACI 506R, Gradation No. 1 with 100 percent passing 3/8-inch sieve.
- D.** Lightweight Aggregates: ASTM C 330.
1. Aggregate Gradation: ACI 506R, Gradation No. 1 with 100 percent passing 3/8-inch sieve.
- E.** Water: Potable, complying with ASTM C 94/C 94M, free from deleterious materials that may affect color stability, setting, or strength of shotcrete.
- F.** Synthetic Fiber: Fibrillated polypropylene fibers engineered and designed for use in shotcrete, complying with ASTM C 1116, Type III, not less than 3/4 inch long.
- G.** Ground Wire: Provide one of the following:
1. High-strength steel wire, 0.8 to 1 mm in diameter.
  2. Stainless steel thickness pins, 0.8 to 1 mm in diameter.
- H.** Joint Filler Strips: ASTM D 1751, asphalt-saturated cellulosic fiber or ASTM D 1752, cork or self-expanding cork.

#### **0.4 CHEMICAL ADMIXTURES**

- A.** General: ASTM C 1141, Class A or B, but limited to the following admixture materials. Provide admixtures for shotcrete that contains not more than 0.1 percent chloride ions. Certify compatibility of admixtures with each other and with other cementitious materials.
  - 1. Air-Entraining Admixture: ASTM C 260.
  - 2. Water-Reducing Admixture: ASTM C 494/C 494M, Type A.
  - 3. Water-Reducing and Retarding Admixture: ASTM C 494/C 494M, Type D.
  - 4. Water-Reducing and Accelerating Admixture: ASTM C 494/C 494M, Type E.
  - 5. High-Range, Water-Reducing Admixture: ASTM C 494/C 494M, Type F.
  - 6. Accelerating Admixture: ASTM C 494/C 494M, Type C.

#### **0.5 CURING MATERIALS**

- A.** Water: Potable.
- B.** Clear, Waterborne, Membrane-Forming Curing Compound: ASTM C 309, Type 1, Class B, as recommended by the shotcrete manufacturer.

#### **0.6 SHOTCRETE MIXTURES (WET AND DRY)**

- A.** General Intent: It is the intent that the prepackaged materials used for this work shall be adequate with a demonstrated successful track record, for the purpose intended and under the conditions normally expected in work of this type. All materials for the shotcrete shall be provided by the same manufacturer.
- B.** Mixes: Provide a prepackaged single component, specially formulated combination of shrinkaged compensated microsilica and fibers along with processed cement and carefully graded aggregate resulting in a high build, low absorption, machine applied mortar. The low water cement ratio will insure high early and ultimate strengths. The combination of microsilica and fibers shall result in a shotcrete with tremendous adhesion to the substrate concrete with extremely low rebound and excellent freeze-thaw resistance.

Property	Conditions	Requirement
Coefficient of Thermal Expansion		6.0 X 10 <sup>-6</sup> deg. C max
Compressive Strength ASTM C-109	@ 1 day	3,000 psi min
-	@ 7 days	6,000 psi min
-	@ 28 days	7,500 psi min
Flexural Strength ASTM C-348	@ 28 days	1,500 psi min
Splitting Tensile Strength ASTM C-882	@ 28 days	650 psi min
Slant Shear Strength ASTM C-88	@ 28 days	2,250 psi min
Water Absorption ASTM C-140		1% absorb max
Freeze-Thaw Resistance MSMT-725, MDDOT	@ 28 days	-0.162% max
Setting time		
Working Time		45 minutes max
Initial Set	@ 75°F 50% RH	2 hours max
Final Set	@ 75°F 50% RH	3 hours max
Shrinkage ASTM C-157	@ 28 days	0.04% max
Wet Density		130 lb/cf (min.)

## 0.7 SHOTCRETE EQUIPMENT

- A. Mixing Equipment: Capable of thoroughly mixing shotcrete materials in sufficient quantities to maintain continuous placement, as recommended by the shotcrete manufacturer.
- B. Dry-Mix Delivery Equipment: Capable of discharging aggregate-cement mixture into delivery hose under close control and maintaining continuous stream of uniformly mixed materials at required velocity to discharge nozzle. Equip discharge nozzle with manually operated water-injection system for directing even distribution of water to aggregate-cement mixture.
  1. Provide uniform, steady supply of clean, compressed air rated to deliver air at 350-750 CFM to maintain constant nozzle velocity while simultaneously operating blow pipe for cleaning away rebound.
  2. Use a rotary pot-type shotcrete machine with a Browning-type nozzle. Provide hoses of sufficient size to allow rapid delivery of the dry mix shotcrete to the nozzle.
  3. Provide water supply with uniform pressure at discharge nozzle to ensure uniform mixing with aggregate-cement mix. Provide water pump to system if line water pressure is inadequate.

4. Provide a premoistener at the dry mix pump for minimizing dust for work within the tunnels, or as directed by the Authority.
- C. Wet-Mix Delivery Equipment:** Capable of discharging aggregate-cement-water mixture accurately, uniformly, and continuously.
1. Use a rotary stator pump capable of introducing materials to the delivery hose at a uniform rate, with ejection from the nozzle at velocities that will afford adherence of material to the surface to be treated with a minimum rebound and maximum adherence and density. Swing tube shotcrete pumps will not be allowed.
  2. The air compressor shall be rated between 350 - 750 cubic feet per minute and capable of 100 - 125 psi pressure. Gunning is performed at 50 - 85 psi or as recommended by the product manufacturer.
  3. The nozzle shall be a center feed nozzle, Thompson type, or approved equal.
  4. Hoses shall be made for wet-process shotcrete with pure gum rubber tube, good flexibility and high resistance to kinking. The contractor shall submit for approval by the Engineer a suitable method of ducting through the fresh air flues. Hose length is limited to a maximum of 100 feet from pump to nozzle and must be no larger than 2 inches in diameter.

## **0.8 BATCHING AND MIXING**

- A. Dry-Mix Process:** Measure mix proportions by weight batching according to ASTM C 94/C 94M or by volume batching complying with ASTM C 685/C 685M requirements, or as recommended by the shotcrete manufacturer.
1. In volume batching, adjust fine-aggregate volume for bulking. Test fine-aggregate moisture content at least once daily to determine extent of bulking.
  2. Prepackaged shotcrete materials may be used at Contractor's option. Predampen prepackaged shotcrete materials and mix before use.
- B. Wet-Mix Process:** Measure, batch, mix, and deliver shotcrete according to ASTM C 94/C 94M and furnish batch ticket information.
1. Comply with ASTM C 685/C 685M when shotcrete ingredients are delivered dry and proportioned and mixed on-site.

## **PART 3 - EXECUTION**

### **0.1 PREPARATION**

- A. General Inspection:** Prior to installation of materials, inspect the substrate and report any unsatisfactory conditions. Commencement of work shall constitute Contractor's acceptance of substrate.

**B. Concrete :**

1. Areas to be patched or resurfaced shall be clean, sound and free of standing or flowing water. The concrete surface and exposed reinforcing steel, shall be waterblasted at a pressure in excess of 2,500 psi to remove all contaminants and rust. Only areas that can be successfully shotcreted in one shift shall be cleaned and have shotcrete applied. If cleaned areas are not shotcreted during the same shift, cleaning that area shall be rewashed by the contractor at no expense to the owner.
2. The demolition of the existing shotcrete shall be performed by using chipping hammers, Pavement breakers and robotic demolition equipment will not be allowed. The Chipping Hammer must not exceed 30 pounds with the bit removed. Aluminum chipping hammers will not be allowed.
3. Where reinforcing steel is encountered with insufficient concrete cover, less than 2 in., the concrete around and under the bar(s) shall be chipped out to a depth where the bar(s) covered with at least 1 in. of shotcrete. Any reinforcing that has been exposed shall be realigned, if required, to ensure proper concrete cover. Embedded steel that has been completely exposed shall be cleaned of loose scale and corrosion prior to shotcrete repair application.
4. The contractor shall replace missing or deteriorated reinforcing steel as directed.
5. Abrasive blast or hydroblast existing surfaces that do not require chipping to remove paint, oil, grease, or other contaminants and to provide roughened surface for proper shotcrete bonding.

**C.** Earth: Compact and trim to line and grade before placing shotcrete. Do not place shotcrete on frozen surfaces. Dampen surfaces before shotcreting.

**D.** Rock: Clean rock surfaces of loose materials, mud, and other foreign matter that might weaken shotcrete bonding.

**E.** Steel: Clean steel surfaces by abrasive blasting according to SSPC-SP 6/NACE No. 3, "Commercial Blast Cleaning".

**0.2 FORMS**

**A.** General: Design, erect, support, brace, and maintain forms, according to ACI 301, to support shotcrete and construction loads and to facilitate shotcreting. Construct forms so shotcrete members and structures are secured to prevent excessive vibration or deflection during shotcreting.

1. Fabricate forms to be readily removable without impact, shock, or damage to shotcrete surfaces and adjacent materials.
2. Construct forms to required sizes, shapes, lines, and dimensions using ground wires and depth gages to obtain accurate alignment, location, and grades in finished structures. Construct forms to prevent mortar

leakage but permit escape of air and rebound during shotcreting. Provide for openings, offsets, blocking, screeds, anchorages, inserts, and other features required in the Work.

- B.** Form openings, chases, recesses, bulkheads, keyways, and screeds in formwork. Determine sizes and locations from trades providing such items. Accurately place and securely support items built into forms.

### **0.3 STEEL REINFORCEMENT**

- A.** General: Comply with CRSI's "Manual of Standard Practice" for fabricating, placing, and supporting reinforcement.
- B.** Clean reinforcement of loose rust and mill scale, earth, ice, and other materials that weaken shotcrete bonding.
- C.** Securely embed reinforcing anchors into existing substrates, located as required.
- D.** Accurately position, support, and rigidly secure reinforcement against displacement by formwork, construction, or shotcreting. Locate and support reinforcement by metal chairs, runners, bolsters, spacers, and hangers, as required.
- E.** Place reinforcement to obtain minimum coverage for shotcrete protection. Arrange, space, and securely tie bars and bar supports to hold reinforcement in position during shotcreting. Set wire ties with ends directed into shotcrete, not toward exposed shotcrete surfaces.
- F.** Install welded wire fabric in lengths as long as practicable. Lap adjoining pieces at least one full mesh and lace splices with wire. Offset laps of adjoining widths to prevent continuous laps in either direction.
- G.** Welded wire fabric, of the size and spacing of wire as shown on the plans, shall be cut to fit the shape of the patch and fastened securely in place. Use approved spacers and tie wire at 16 inch intervals in both directions. Install fasteners around the perimeter of the welded wire fabric at a 16 inch interval. Wire fabric shall not be placed and secured until the abrasive blasting is completed.

### **0.4 JOINTS**

- A.** Construction Joints: Locate and install construction joints tapered to a 1:1 slope where joint is not subject to compression loads and square where joint is perpendicular to main reinforcement. Continue reinforcement through construction joints, unless otherwise indicated.

- B.** Contraction Joints: Construct contraction joints in shotcrete using saw cuts 1/8-inch-wide-by-1/3 slab depth or joint-filler strips 1/4-inch-wide-by-1/3 shotcrete depth, unless otherwise indicated.

1. After shotcrete has cured, remove strip inserts and clean groove of loose debris.
2. Space joints at centers indicated horizontally and vertically.
3. Tool edges round on each side of strip inserts if floated or troweled finishes are required.

## **0.5 ALIGNMENT CONTROL**

- A.** Ground Wires: Install ground wires to establish thickness and planes of shotcrete surfaces. Install ground wires at corners and offsets not established by forms. Pull ground wires taut and position adjustment devices to permit additional tightening.

1. Stainless steel thickness pins may be used as a substitute for ground wires.

## **0.6 EMBEDDED ITEMS**

- A.** Place and secure anchorage devices and other embedded items required for adjoining work that is attached to or supported by shotcrete. Use setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

## **0.7 APPLICATION**

- A.** Apply temporary protective coverings and protect adjacent surfaces against deposit of rebound and overspray or impact from nozzle stream.
- B.** Moisten wood forms immediately before placing shotcrete where form coatings are not used.
- C.** Apply shotcrete according to ACI 506.2.
- D.** Apply dry-mix shotcrete materials within 45 minutes after predampening and wet-mix shotcrete materials within 90 minutes after batching.
- E.** Deposit shotcrete continuously in multiple passes, to required thickness, without shadowing, cold joints, or laminations developing. Place shotcrete with nozzle held perpendicular to receiving surface. Begin shotcreting in corners and recesses.
1. Remove and dispose of rebound and overspray materials during shotcreting to maintain clean surfaces and to prevent rebound entrapment.

- F.** Maintain reinforcement in position during shotcreting. Place shotcrete to completely encase reinforcement and other embedded items. Maintain steel reinforcement free of overspray and prevent buildup against front face during shotcreting.
- G.** Do not place subsequent lifts until previous lift of shotcrete is capable of supporting new shotcrete.
- H.** Do not permit shotcrete to sag, slough, or dislodge.
- I.** Remove hardened overspray, rebound, and laitance from shotcrete surfaces to receive additional layers of shotcrete; dampen surfaces before shotcreting.
- J.** Do not disturb shotcrete surfaces before beginning finishing operations.
- K.** Remove ground wires or other alignment control devices after shotcrete placement.
- L.** Shotcrete Core Grade: Apply shotcrete to achieve mean core grades not exceeding 2.5 according to ACI 506.2, with no single core grade exceeding 3.0.
- M.** Installation Tolerances: Place shotcrete without exceeding installation tolerances permitted by ACI 117R, increased by a factor of 2.

## **0.8 SURFACE FINISHES**

- A.** General: Finish shotcrete according to descriptions in ACI 506R for the following finishes:
- B.** Natural Finish:
  - 1. Gun Finish: Natural undisturbed finish.
- C.** Finish-Coat Finish: After screeding and rodding surface, apply shotcrete finish coat, 1/4 to 1 inch thick, using ACI 506R, Gradation No. 1, fine-screened sand modified with maximum aggregate size not exceeding No. 4 sieve to provide a finish of uniform texture and appearance.
- D.** Wood Float: After screeding surface, finish the shotcrete using a wood float.
- E.** Steel Trowel: Finish the shotcrete using a steel trowel, in locations where a smooth finish is required.

## **0.9 CURING**

- A.** Protect freshly placed shotcrete from premature drying and excessive cold or hot temperatures.
- B.** Start initial curing as soon as free water has disappeared from shotcrete surface after placing and finishing.
- C.** Curing Exposed Surfaces: Cure shotcrete by one of the following methods:
  - 1. Moisture Curing: Keep surfaces continuously moist for at least five days with water, continuous water-fog spray, water-saturated absorptive covers, or moisture-retaining covers. Lap and seal sides and ends of covers.
  - 2. Curing Compound: Apply curing compound uniformly in continuous operation by power spray according to manufacturer's written instructions. Recoat areas subjected to heavy rainfall within three hours after initial application. Maintain continuity of coating and repair damage during curing period.
    - a. Apply curing compound to natural or gun-finished shotcrete at rate of 1 gal./100 sq. ft.
- D.** Curing Formed Surfaces: Cure formed shotcrete surfaces by moist curing with forms in place for full curing period or until forms are removed. If forms are removed, continue curing by methods specified above, as applicable.

## **0.10 FORM REMOVAL**

- A.** Forms not supporting weight of shotcrete may be removed after curing at not less than 50 deg F for 24 consecutive hours after gunning, provided shotcrete is hard enough not to be damaged by form-removal operations and provided curing and protecting operations are maintained.
  - 1. Leave forms supporting weight of shotcrete in place until shotcrete has attained design compressive strength. Determine compressive strength of in-place shotcrete by testing representative field-cured specimens of shotcrete.
  - 2. Remove forms only if shores have been arranged to permit removal of forms without loosening or disturbing shores.
- B.** Clean and repair surfaces of forms to be reused in the Work. Split, frayed, delaminated, or otherwise damaged form-facing materials are unacceptable for exposed surfaces. Apply new form-coating compound as specified for new formwork.

## **0.11 FIELD QUALITY CONTROL**

- A.** Contractor shall engage a qualified independent testing agency to sample materials, visually grade cores, perform tests, and submit reports during shotcreting.
- B.** Shotcrete Temperature: ASTM C 1064/C 1064M; 1 test hourly when air temperature is 40 deg F and below and when 80 deg F and above, and 1 test for each set of compressive-strength specimens.
- C.** Test Panels: Make a test panel, reinforced as in structure, for each shotcrete mix and for each workday or for every 50 cu. yd. of shotcrete placed; whichever is less. Produce test panels with dimensions of 24 by 24 inches minimum and of average thickness of shotcrete, but not less than 4-1/2 inches. From each test panel, testing agency will obtain six test specimens: one set of three specimens unreinforced and one set of three specimens reinforced.
  - 1. Test each set of unreinforced specimens for compressive strength according to ASTM C 1140 and construction testing requirements in ACI 506.2.
  - 2. Visually inspect each set of reinforced shotcrete cores taken from test panels and determine mean core grades according to ACI 506.2.
- D.** In-Place Shotcrete: Take a set of 3 unreinforced cores for each mix and for each workday or for every 50 cu. yd. of shotcrete placed; whichever is less. Test cores for compressive strength according to ACI 506.2 and ASTM C 42. Do not cut steel reinforcement.
- E.** Strength of shotcrete will be considered satisfactory when mean compressive strength of each set of 3 unreinforced cores equals or exceeds 85 percent of specified compressive strength, with no individual core less than 75 percent of specified compressive strength.
  - 1. Mean compressive strength of each set of 3 unreinforced cubes shall equal or exceed design compressive strength with no individual cube less than 88 percent of specified compressive strength.

## **0.12 REPAIRS**

- A.** Remove and replace shotcrete that is delaminated or exhibits laminations, voids, or sand/rock pockets exceeding limits for specified core grade of shotcrete.
  - 1. Remove unsound or loose materials and contaminants that may inhibit bond of shotcrete repairs. Chip or scarify areas to be repaired to extent necessary to provide sound substrate. Cut edges square and 1/2 inch deep at perimeter of work, tapering remaining shoulder at 1:1 slope into cavity to eliminate square shoulders. Dampen surfaces and apply new shotcrete.

- B.** Repair core holes from in-place testing according to repair provisions in ACI 301 and match adjacent finish, texture, and color.

### **0.13 CLEANING**

- A.** Remove and dispose of rebound and overspray materials from final shotcrete surfaces and areas not intended for shotcrete placement.

## **PART 4 - MEASUREMENT AND PAYMENT**

### **0.1 MEASUREMENT**

- A.** Shotcrete will be measured complete in place, by the cubic yard, including temporary scaffolding and incidentals required for the shotcrete application, providing and placement of curing compound, services of the manufacturer's representative and cleanup. There shall be no payment for shotcrete which is used to charge the dispensing system, and other material which is lost due to overspray or waste. Measurement of shotcrete shall be made on a daily basis and agreed to by all parties on a daily basis. The rebound and waste shall not be measured for payment. There will be no separate measurement or payment for maintenance of the mechanical or electrical systems, the control of standing water (dewatering), or any other incidental items required to perform this work. All of these items are considered incidental to the work.

### **0.2 PAYMENT**

- A.** Payment for shotcrete will be made at the Contract unit prices as specified above.

### **0.3 PAYMENT ITEMS**

ITEM NO.	DESCRIPTION	UNIT
0310.081	SHOTCRETE	CY

END OF SECTION

## **NOTES TO THE DESIGNER**

- A.** Any request to modify or waive the specification requirements listed below must be approved in writing by the MBTA's Director of Design:
1. All shotcrete work must be performed by an American Concrete Institute (ACI) approved nozzleman.